Adrenal Imaging with Multidetector CT: Evidence-based Protocol Optimization and Interpretative Practice[1]

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tion, there are several CT findings that contribute to the diagnosis, including lesion size, attenuation value before injection of contrast material (ie, precontrast attenuation), level of enhancement at 60 seconds after injection (ie, portal venous phase postcontrast attenuation) and several minutes after injection (ie, delayed postcontrast attenuation), percentage washout on delayed images, results of histogram analysis, and extent (involvement of the inferior vena cava [IVC] and bilaterality). In the past decade, a body of pertinent

Lesion Size

ever, there is considerable overlap (2). A definitive size threshold cannot be used to confidently distinguish benign from malignant lesions with diameter as the only imaging finding (Table 1) (3–9). The appropriateness criteria of the American College of Radiology emphasize that management with respect to lesion size depends on whether patients have a history of malignancy; in those who do not, benign-appearing tumors smaller than 3 cm likely are benign (3). Excision is generally advised for incidentally discovered masses larger than 5 cm (3).

Table 1
Studies that Measured the Utility of Size Thresholds in Distinguishing Benign from Malignant Lesions

Study*	No. of Adenomas	No. of Non-adenomas	Size Cutoff (cm)	Sensitivity (%)	Specificity (%)
Lee et al 1991 (4)	38	28	2.5	84	79
Szolar and Kammerhuber 1997 (5)	41	37	2.5	66	84
Szolar et al 2005 (6)	24	49	2.5	75	88
Park et al 2007 (7)	25	20	2	20	100
			4	92	70
Ctvrtlik et al 2008 (8)	37	25	4.15	81	70

*Numbers in parentheses are references.

Precontrast Attenuation

Many investigators use a cutoff of less than 10 HU to diagnose an adenoma, a technique supported by the American College of Radiology appropriateness criteria (3). Despite variable sensitivity with this cutoff, adenomas with higher precontrast attenuation may still be identified as such by performing delayed contrast material–enhanced CT to measure washout characteristics, which are described later.

Venous Phase Postcontrast Attenuation

Venous phase postcontrast findings remain important because they are used to calculate washout and because absolute enhancement levels can be used to distinguish a pheochromocytoma from an adenoma. Pheochromocytomas may display high levels of enhancement and generally enhance to a greater degree than adenomas do, findings that were described in two investigations that compared aden[...]
the dynami[...]

Table 3
Comparison of Postcontrast Attenuation of Adenomas and Pheochromocytomas

Study*	No. of Adenomas	No. of Pheochromocytomas	Acquisition Timing	Mean Postcontrast Attenuation (HU)† Adenomas	Mean Postcontrast Attenuation (HU)† Pheochromocytomas
Szolar et al 2005 (6)	24	17	60 sec	60 (30–84)	94 (72–131)
Ctvrtlik et al 2008 (8)	37	9	Not reported	36.7 (3–95)	78.7 (50–111)

Note.—Some attenuation values are rounded up.
*Numbers in parentheses are references.
†Numbers in parentheses are ranges.

Delayed Postcontrast Attenuation

Table 4
Studies that Measured the Utility of Delayed Postcontrast Attenuation Thresholds in Distinguishing Adenomas from Nonadenomas

Study*	No. of Adenomas	No. of Non-adenomas	Timing of Delayed Acquisition	Delayed Attenuation Cutoff (HU)	Sensitivity (%)	Specificity (%)
Korobkin et al 1996 (18)	41	10	Approximately 1 h after initial acquisition† (mean)	30	95	100
Szolar and Kammerhuber 1997 (5)	41	37	180 sec after start of injection; 30 min after start of injection‡	64 40	91 100	100 100
Boland et al 1997 (19)	23	23	14 min after start of injection (mean)	24	96	96
Korobkin et al 1998 (11)	52	24	15 min after initial acquisition†	37	96	96
Szolar and Kammerhuber 1998 (12)	74	61	10 min after start of injection; 30 min after start of injection	52 37	92 97	95 100
Pena et al 2000 (13)	61§	40	9 min after initial acquisition† (mean)	30	80	100
Szolar et al 2005 (6)	24	49	10 min start of injection	52	92	96

Note.—Some attenuation values are rounded up.
*Numbers in parentheses are references.
†Interval from the end of the first postcontrast acquisition.
‡Recommended by authors.
§Includes myelolipomas.

Percentage Washout

$$APW = 100 \times (VA - DA)/(VA - PCA)$$

$$RPW = 100 \times (VA - DA)/VA,$$

were proposed as thresholds. Regardless of lipid content, adenomas typically wash out more than 60% (APW) or 40% (RPW), whereas metastases, adrenocortical carcinomas, and some pheochromocytomas usually wash out to a lesser degree

Histogram Analysis

trast-enhanced CT scans. Results vary, with some studies showing high specificity when thresholds of more than 5% and more than 10% negative-attenuation pixels were used with unenhanced scans (22–26). However, other studies have iden-

Extent

Table 6
Differential Diagnosis for Bilateral Adrenal Masses

Lesion	Frequency of Bilaterality
Metastases	50%
Lymphoma	50% of secondary lymphomas
Granulomatous infection	Usually bilaterally asymmetric
Adenoma	20%
Pheochromocytoma	10%
Hyperplasia	Usually bilaterally symmetric
Myelolipoma	5%–13% of cases
Adrenocortical carcinoma	2%–6% of cases
Hemorrhage	Depends on the cause

Take-Home Points

The size of an adrenal mass contributes to the diagnosis, but by itself it is not a definitive indicator of malignancy. In patients with no history of malignancy, benign-appearing masses that are smaller than 3 cm likely are benign, whereas those larger than 5 cm often are resected.

Precontrast attenuation of less than 10 HU is used by many authors to identify lipid-rich adenomas.

Homogeneous masses with more than 60% APW or more than 40% RPW, in conjunction with portal phase absolute enhancement levels of less than 100 HU, likely are adenomas.

A mass with washout of more than 60% APW or more than 40% RPW, but with absolute enhancement of more than 110–120 HU, is suggestive of pheochromocytoma.

Bilaterality is more common in metastases, lymphoma, infection, hyperplasia, and hemorrhage, whereas adenomas, pheochromocytomas, adrenocortical carcinomas, and myelolipomas are bilateral in less than 30% of cases.

CT Technique

Incidental Masses

Protocol optimization depends on the images that were acquired when the mass was first discovered. If unenhanced imaging was performed, lesions less than 10 HU generally are considered adenomas (Fig 1) (3). If the mass is indeterminate (<4 cm, but >10 HU on precontrast CT scans), then dynamic and delayed imaging may be performed to determine the degree of enhancement, APW, and RPW. For a lesion discovered in a single portal venous phase acquisition, delayed imaging is performed 10–15 minutes after administration of contrast material to calculate the RPW. Absolute enhancement on portal phase images is important as an isolated measurement, not to diagnose an adenoma, but to identify a pheochromocytoma. Pheochromo-

Known or Suspected Adrenal Lesions

When oral contrast material is being used, we administer 1000 mL of water at the time of the study. With a 64-row multidetector CT scanner, the parameters are as follows: 0.6-mm detectors, 120 kVp, 200–250 mAs (effective), and 370-msec rotation time. Two sets of reconstructions are performed (0.75 × 0.5 mm and 3 × 3 mm). If the attenuation is less than 10 HU and the mass is smaller than 4 cm on unenhanced images, the diagnosis is an adenoma. For lesions with attenuation of more than 10 HU, we administer 100 mL of iohexol 350 (iodine, 350 mg/mL) at a rate of 3–4 mL/sec and we acquire data 60 seconds and 15 minutes after initiation of contrast material infusion. Our cutoff to diagnose an adenoma is an APW of more than 60% or an RPW of more than 40%.

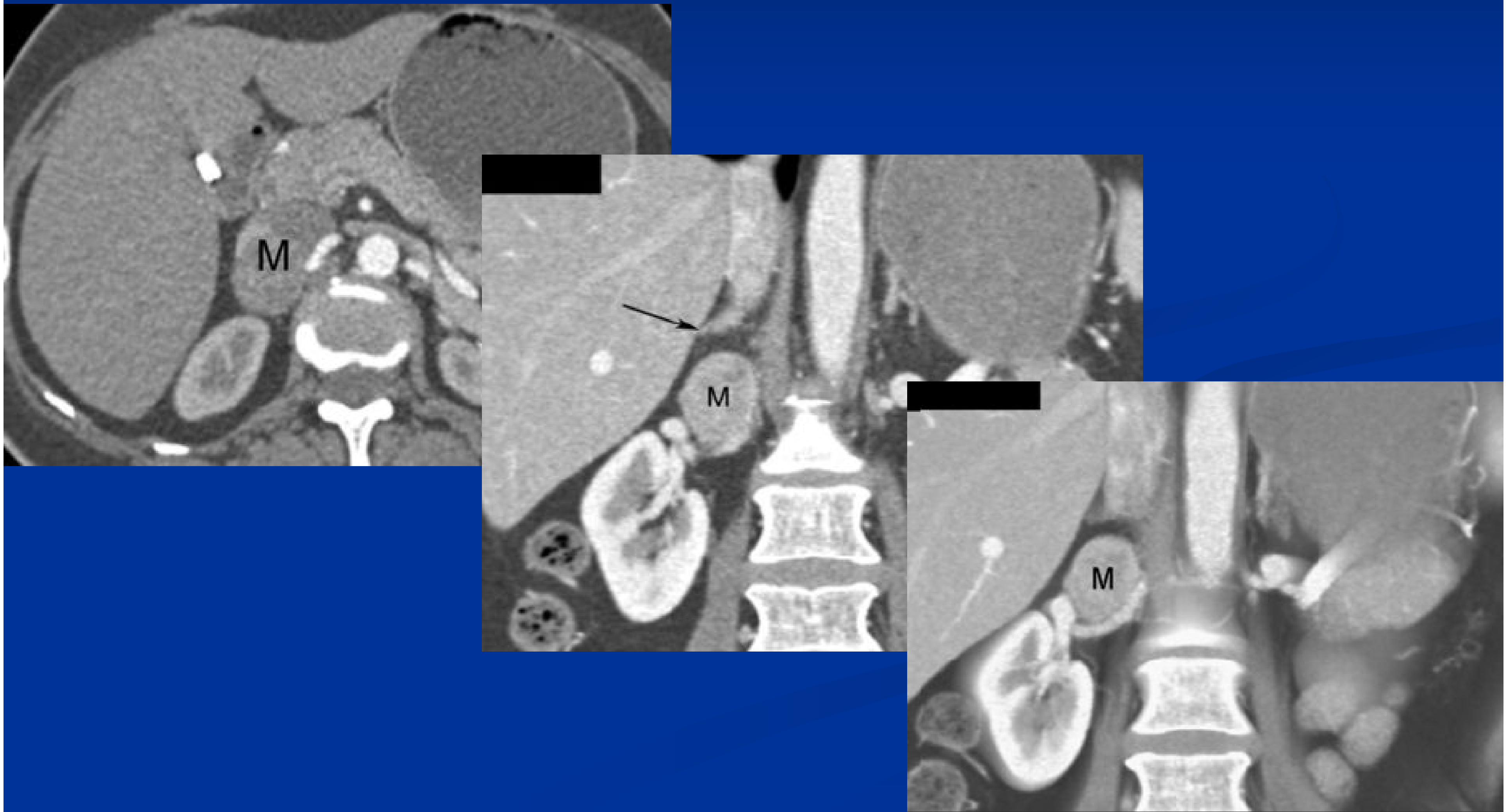
Adrenal Cancer Staging

In a patient known or suspected to have adrenal cancer, dual-phase CT is performed with 100–120 mL of contrast material with an iodine concentration of 350 mg/mL, which is infused at a rate of 3–4 mL/sec. Precontrast images are not acquired. When a 64-row multidetector CT scanner is used, the parameters are as follows: 0.6-mm detectors, 120 kVp, 200–250 mAs (effective), and 370-msec rotation time. Two data sets are reconstructed at 0.75 × 0.5 mm and 3 × 3 mm. After the arterial phase images are acquired, typically with an approximately 25-second delay, venous phase images are acquired with a 60–70 second delay to evaluate for renal vein and IVC invasion. Because of this, imaging must extend through the base of the heart.

Pheochromocytoma

We do not require that patients with known or suspected pheochromocytoma be premedicated. We administer 1000 mL of water orally and 100–120 mL of intravenous contrast material (iodixanol [iodine, 320 mg/mL]) at a rate of 4 mL/sec, and we acquire images at 25 seconds and 60 seconds after initiation of contrast material infusion. If there is a high clinical suspicion of pheochromocytoma and the adrenal glands are normal, it is prudent to scan from the diaphragm to the pelvis to search for extraadrenal pheochromocytomas along the region of the aorta, especially near the organs of Zuckerkandl and the bladder.

Postprocessing and Display



Conclusions

It is important to develop a well-defined strategy for dealing with adrenal masses to minimize unnecessary expenses and stress for patients and to provide optimal care. Various CT findings have been tested and found to be reliable for identifying adenomas and pheochromocytomas. This review of the body of evidence in the literature on adrenal CT provides specific guidance for design of acquisition protocols and interpretation of images.